

# Scoping natural language processing in Indonesian and Malay for education applications

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## Abstract

Indonesian and Malay are underrepresented in the development of natural language processing (NLP) technologies and available resources are difficult to find. A clear picture of existing work can invigorate and inform how researchers conceptualise worthwhile projects. Using an education sector project to motivate the study, we conducted a wide-ranging overview of Indonesian and Malay human language technologies and corpus work. We charted 657 included studies according to Hirschberg and Manning’s 2015 description of NLP, concluding that the field was dominated by exploratory corpus work, machine reading of text gathered from the Internet, and sentiment analysis. In this paper, we identify most published authors and research hubs, and make a number of recommendations to encourage future collaboration and efficiency within NLP in Indonesian and Malay.

## 1 Introduction

Limited natural language processing (NLP) resources currently available for Indonesian and Malay varieties do not reflect large speaker populations of these languages in Indonesia, Malaysia, and other South-East Asian nations<sup>1</sup>. Difficulties locating resources and existing work hinders progress in the field; it can result in duplicated or unnecessary work, clouding the ability of researchers to formulate useful research questions and study designs. Since Indonesian and Malay varieties are closely related (Sneddon, 2003; Basuki and Antaputra, 2020b), connecting research and

technologies developed for either language could provide useful insights and shortcuts for work in the other language.<sup>2</sup>

These challenges restrict the impact that advances in NLP might have in the education sector in Indonesia and Malaysia, and in the teaching of these languages. Ideally, teachers of Indonesian or Malay as a second or foreign language would draw on a wide range of human language technologies, machine learning methods, and corpus linguistics tools to enhance teaching and learning outcomes<sup>3</sup>.

As part of a broader project investigating teacher-speech and materials for Indonesian language teaching (Maxwell-Smith et al., 2020; Maxwell-Smith, 2021), the aims of this study were to scope the state of play of existing work in Indonesian and Malay NLP to assist in the formulation of realistic research goals, and to identify useful networks and resources. As such, our study draws on the notion of scoping work as “reconnaissance” (Peters et al., 2015), where the goal is to first determine what range of quantitative and/or qualitative evidence is available on a topic and then to chart, map, or otherwise represent this located evidence visually.

Our research questions were as follows:

1. What language technologies and NLP resources exist for Indonesian/Malay (and therefore for education sector applications)?
2. How do they align with the trends seen more widely in NLP?

We begin by describing our search strategy and methods for charting 657 included studies by their

<sup>1</sup>In 2011, the Indonesian Census recorded 197 million Indonesians as literate in Indonesian (Zein, 2020). In Malaysia, nearly the whole population speak Malay as a first or additional language (Coluzzi, 2017); in 2021, according to the Department of Statistics Malaysia, this was about 32 million people.

<sup>2</sup>As indicated in Lin et al. (2019c) and Nomoto et al. (2018a), some significant differences should caution NLP researchers from regarding the Indonesian and Malay languages as one.

<sup>3</sup>See for example Lee et al. (2020) in journals such as CALL and LLT.

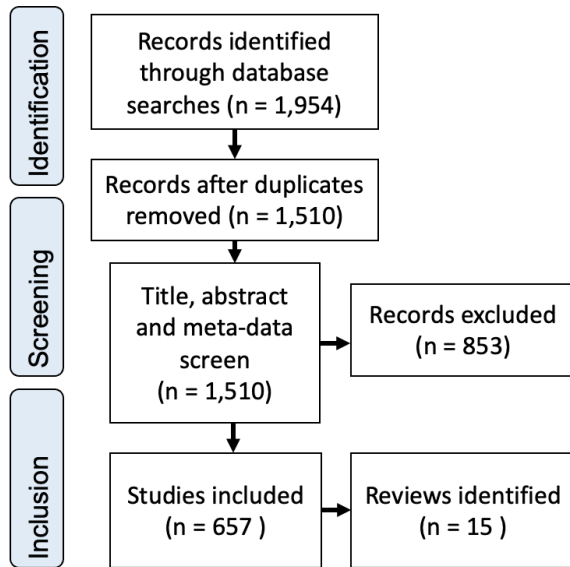


Figure 1: Screening Process and Study Selection

topic and year of publication. We summarize existing literature reviews and notable work, graph most published authors and their affiliated research hubs, and describe recent educational applications of NLP. Finally, we make 7 recommendations to build collaboration and efficiency in Indonesian and Malay NLP, highlighting our contribution to these goals.

## 2 Methods

In order to capture a broad and rich picture of the recent literature, we applied a simplification of the Systematic Reviews and Meta-Analyses (PRISMA) for scoping reviews (Tricco et al., 2018; Page et al., 2021). Generally, we aimed to provide a descriptive overview and visualization of the reviewed material without detailed critical appraisal of individual studies or synthesis of evidence from different studies (Pham et al., 2014; Peters et al., 2015).

The review engaged with literature from many disciplines, including, but not limited to, Computational Linguistics, Computer Science, Indonesian Language Teaching, and NLP. Extensive consultations with research librarians resulted in a broad search strategy of the databases and terms (Figure 2). Both Indonesian/Malay and English search terms were used to maximize coverage. Additional search terms focused on our interest in Indonesian language teaching were used to mitigate the risk of missing relevant literature.

We experienced significant problems identifying studies with the Association for Computational Lin-

guistics (ACL) as their publisher. In searches via Google Scholar, Scopus, and Proquest; many ACL publications (e.g., Koto et al. (2020a) and Wilie et al. (2020)) were not returned<sup>4</sup>. We then added a direct ACL Anthology search to our database search list. Unexplained behaviour in the ACL Anthology sort by ‘Year of Publication’ functionality cut results by over 400%, missing, for example, the aforementioned two relevant papers. To identify a reasonable portion of the work presented at ACL events, we extended the set of identified records semi-automatically by manually opening and exporting studies from ACL Anthology searches.

Our inclusion criteria specified that studies be recent (published in 2016 or later), peer-reviewed, written in English, Indonesian or Malay, and relevant to our topic (work about other languages or unrelated to NLP was excluded). Topical relevance was determined by a single reviewer (the first author of this paper) screening the title, abstract, and metadata of each identified study ( $n = 1,954$ ) that was unique ( $n = 1,510$ ) (Figure 1).

Included studies were then classified according to Hirschberg and Manning’s 2015 characterization of advances in NLP. We refer to these classifications in brief as: *Broad NLP*; *Machine Reading*; *Machine Translation*; *Spoken Dialogue Systems*; *Speaker State*; and *Social Media*. We added a class — *Statistical Work* — to group work which primarily contributes corpus data or statistical and pre-processing work which stands at the foundation of most NLP.

Two reviewers (the first and last author of this paper) worked as a classification team, thereby assuring the quality of this ‘light-touch’ manual content analysis (Saldaña, 2016). In total, 80 of the 657 included studies (12.2%) were classified independently by both reviewers, including studies whose classification was perceived as uncertain by the first reviewer, as well as a random selection of further studies to increase confidence in reviewer agreement. Reviewers’ classification disagreements were resolved through reference to full-text articles and discussion reaching consensus<sup>5</sup>.

While many studies were classified as belonging to more than one ‘grouping’, the primary class was

<sup>4</sup>Not in the top 100 search results on Google Scholar.

<sup>5</sup>Both reviewers are academic researchers in NLP and teachers. Reviewer agreement of classification was very high. Most often the selection of a primary class was discussed and resolved by looking beyond brief, and at times misleading, information in article abstracts.

| Database/Search Engine and search date/details                                                  | NLP and Indonesian/Malay keywords                                                                                                                                                                                                                                  | Additional education keywords added to search string                                                                                                                                                                                                |
|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Scopus<br/>ProQuest<br/>EBSCO</b><br><br><b>Limited to peer-review<br/>21 October 2021</b>   | ("natural language processing" OR nlp OR corpus OR corpora OR "computational linguistics" OR "pemrosesan bahasa alami" OR "pengolahan bahasa alami" OR korpus OR korpora OR "linguistik komputasional") AND ("indonesian language" OR "bahasa indonesia" OR malay) | AND ("language teaching" OR "language learning" OR "foreign language" OR bipa OR tipl OR tisol OR "belajar bahasa")                                                                                                                                 |
| <b>Google</b><br><br><b>Reduced length due to<br/>character limit</b><br><br><b>8 July 2021</b> | ("natural language processing" OR corpus OR corpora OR "computational linguistics" OR "pemrosesan bahasa alami" OR "pengolahan bahasa alami" OR korpus OR korpora OR "linguistik komputasional") AND ("indonesian language" OR "bahasa indonesia" OR malay)        | ("natural language processing" OR corpus OR "computational linguistics" OR "pemrosesan bahasa alami" OR korpus OR "linguistik komputasional") AND (indonesia OR malay) AND ("language teaching" OR "language learning" OR bipa OR "belajar bahasa") |
| <b>ACL Anthology</b><br><br><b>25 October 2021</b>                                              | (indonesian OR malay OR bahasa) AND ("language teaching" OR "language learning" OR "foreign language")                                                                                                                                                             | indonesian OR malay OR bahasa                                                                                                                                                                                                                       |

Figure 2: Search Strategy

used in our analysis below. Appendix B is sorted by the second and third classification levels to improve search-ability and provide further information.

A search of titles and abstracts uncovered pre-existing reviews. These reviews were screened in full text and their findings are outlined in our results section to complement the scoping or quantitative map of the field. Literature outside our inclusion criteria which appeared highly relevant was retained separately for full-text review.

Unique names in the raw list of the top 50 most-published authors were manually normalized to prepare a publication-by-author count. Manual identification of name variants for authors with many publications were identified by matching author initials, affiliations, and profiles where possible to create Figure 5. Author affiliations for Figure 6 were taken from the most recent study of a given author included in this overview.

### 3 Results

A total of 657 from 1,954 studies met our inclusion criteria. Statistical and corpus work dominated throughout the last 5 years (from 2016 — Figure 3). Studies related to machine reading and sentiment analysis of online text such as news websites (included in ‘Speaker States’) and social media (sentiment analysis comprises much of our ‘Social Media’ classification) were popular and showed growth (Figure 4). The largest growth area was in



Figure 3: Indonesian and Malay NLP Research in 2016–2021

‘Speaker Dialogue Systems’ with a relative boom in publishing in 2019 (26 studies).

While our search terms were bilingual, the majority of studies that met our inclusion criteria were written in English or had an English title and abstract. The apparent stagnation of publications in 2020 (Figure 4) with a rebound in the first half of 2021 (which our search covered) could be related to the context of the COVID19 pandemic.

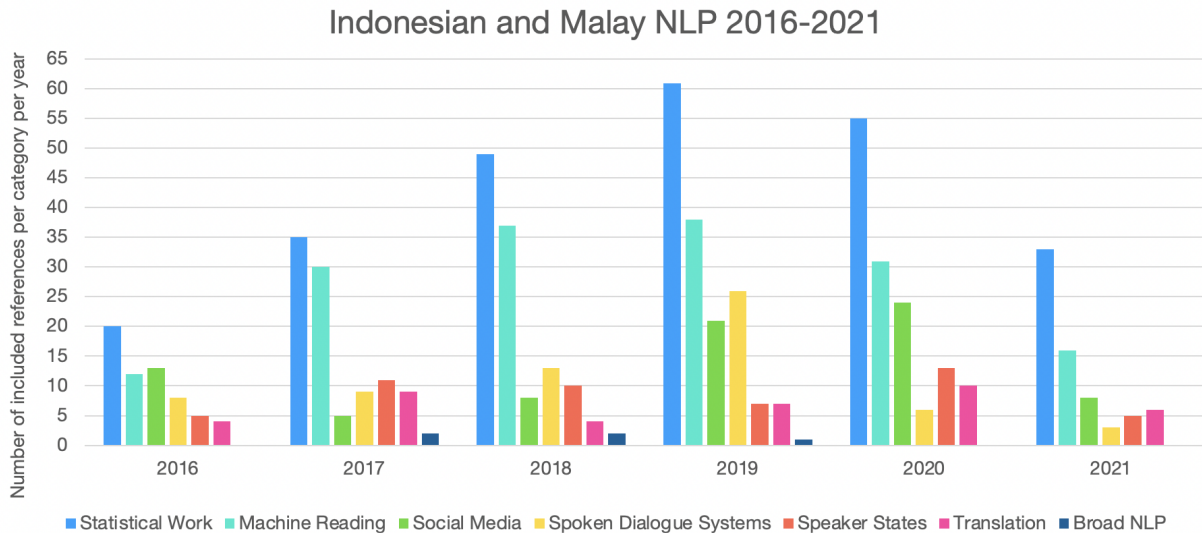


Figure 4: Categorisation of Indonesian and Malay NLP Research in 2016–2021 by Year

However, as “country-specific variables play a significant role” (Abramo et al., 2022) in pandemic publication trends, this is very difficult to determine.

As noted by Hirschberg and Manning in 2015, machine reading research makes use of the vast quantities of text available in the modern world while the mining of text from social media has “revolutionized the amount and types of information available today to NLP researchers”. The presence of work in all classifications indicates Indonesian and Malay NLP has advanced from its 2015 state, when Hirschberg and Manning said it had “no such resources or systems available” (2015). To complement the quantitative picture in Figures 3 and 4, we identified existing reviews and provide a summary below. A detailed full-text review of all articles identified in a given classification is needed to fully investigate progress in each respective field.

### 3.1 Existing Reviews

Of the included studies, 15 were identified as reviews and read in full-text. Lan and Logeswaran (2020) discussed NLP in Indonesian/Malay in general. They did not identify their search methods nor their inclusion criteria, and their reference list had a strong focus on Malaysian research. Their description of statistical work on morphological and lexical analysis, the development of stop word lists, text normalization and named entity recognition concluded that “most researchers have no choice but to resort to compile their own corpus specific to their domain” (Lan and Logeswaran, 2020). According to their discussion, applications of NLP,

such as those for machine translation, sentiment analysis, sarcasm and spam detection, as well as text summarization, were hampered by an absence of language-specific tools and resources. For example, they stated that the Jawi Malay script (which is based on Arabic) appeared to be missing characters, lemmatizers for translation seemed to struggle with affixes as they were loaned from English NLP, and sentiment analysis tended to rely on translated sentiment lexicons.

A 16th review article — “An Overview of Natural Language Processing for Indonesian and Malay” by Jiang et al. (2020), written in Mandarin — was identified at the screening stage. It fell outside the scope of this study but we did note that it provided a detailed overview of Indonesian/Malay NLP. The authors characterized the field as “widely distributed, covering stemming, part-of-speech tagging, syntactic analysis, semantic analysis, and other underlying technologies, as well as upper-level applications such as machine translation, spell checking, sentiment analysis, named entity recognition” (Jiang et al., 2020). However, similarly to Lan and Logeswaran (2020), they noted that “the basic resources, open data platforms and open-source language processing tools for these two languages are also lacking, and there are few mature and available text analysis systems” (Jiang et al., 2020).

Statistical or corpus based NLP is important to further the field; however, only 2 reviews had a special focus on corpora and these were specific to Malay (Awang Abu Bakar et al. (2018) and Nasharuddin et al. (2018)). These reviews provided

some insight into Malay resources, and [Nasharudin et al. \(2018\)](#) suggested document alignment as an avenue to overcome parallel corpus scarcity in cross and bilingual information retrieval, however, a thorough picture of existing corpora was lacking.

A further review by [Kassim et al. \(2016b\)](#) discussed morphology related challenges in stemming tools for Malay as perceived by the authors. However, this review did not fully address the complex steps necessary to uncover lemmas. As later described by [Nomoto \(2020\)](#), what has been “thought of as stemming and lemmatization [...] is in fact ‘root’-ing, that is, undoing all morphological processes to get a root”. Future work needs to make use of the sort of stem and lemma information in [MALINDO Morph](#) to create Indonesian/Malay stemmers.

Machine translation was discussed in a single review of Indonesian translation by [Rahutomo et al. \(2019\)](#)<sup>6</sup>, who identified that many researchers had created their own web-crawled parallel corpora. They described a range of techniques used in Indonesian translation, noting that [Moses](#) was commonly used and that attention-based approaches were improving neural machine translation. Their list of studies spanned languages: Sundanese, Javanese, Lampung, as well as English, Japanese, and Korean — a very limited list given there are between 652–701 languages in use in Indonesia ([Zein, 2020](#)). Thereby translation needs are yet to be met.

Machine reading was the focus of 5 reviews. [Gunawan and Amalia \(2018\)](#) reviewed single document text summarization and identified evaluation methods as a significant concern among 10 papers reporting research into extractive text summarization. They concluded that a text-summary dataset created by experts is needed to advance the field and to calibrate the diverse results reported in the literature.

Looking only at Malay, [Mohemad et al. \(2020b\)](#) suggested relatively poor results across the field. They found summaries were often longer than the original text and Malay anaphora proved difficult to condense, resulting in poor comprehensibility.<sup>7</sup>

In 2021, [Widodo et al.](#) remained concerned with evaluation measures in text summarization. Their review of 6 studies found all text summarization work was in extractive summarization — as op-

posed to abstractive — and that it was dominated by single document summarization of online news. To expand the usability and scope of these tools for Indonesian, they suggested that journal articles should be used as data to support multi-document summarization, as existing summaries of these documents could be used to enhance results.

Malay named entity recognition and classification (NERC) was carefully reviewed by [Mohemad et al. \(2020a\)](#), finding that differences in Malay morphology and textual ambiguities, as well as limitations on corpora and annotated data, are difficult challenges affecting both rule-based and machine learning methods. In addition, they found that the “majority of the systems developed [were] based on manually predefined dictionaries by a human” ([Mohemad et al., 2020a](#)) and that deep learning methods were yet to be studied with Malay NERC.

All 4 reviews of sentiment analysis were primarily concerned with social media in the Malaysian context (see both ‘Speaker States’ and ‘Social Media’ in Appendix B). [Abdullah et al. \(2017\)](#) found hybrid approaches of lexicon based and supervised machine learning were most common, while [Handayani et al. \(2018\)](#) added a more detailed discussion of techniques and datasets found in 10 carefully selected studies. [Abu Bakar et al. \(2020\)](#) foregrounded the ‘noise’ of social media data to confront the more complex language often found on the Internet. [Abdullah and Rusli \(2021\)](#) pushed this further, examining literature on multilingual sentiment analysis to inform the development of sentiment analysis for the Malaysian social media context, which they described as characterized by the multilingual use of English, Malay, and Chinese.

No reviews of spoken dialogue systems, such as automated speech recognition (ASR) or Text To Speech (TTS) toolkits (which are typically considered later-generation NLP), were found. This is not surprising given text-based NLP (e.g., machine reading) dominated the research agenda (Figure 4).

### 3.2 Notable Work Responding to the Lack of Data and Evaluation Methods, and Other Recent Contributions

Common to all reviews was a scarcity of freely available NLP resources, and subsequently the creation of custom datasets, loaned preprocessing tools from NLP in English, and difficulties in benchmarking performance without reliable eval-

<sup>6</sup>see also [Septarina et al. \(2019\)](#)

<sup>7</sup>Providing a brief reference to Malay language corpora, [Omar et al. \(2021\)](#) outlined advances in text summarization techniques.

uation techniques and reference datasets. In this context, we note the growing use of zero and few shot methods which are supported by pipelines such as HuggingFace<sup>8</sup>. We also note four projects and respective papers that develop benchmarking and open access corpora for:

- language modelling; Indonesian Language Evaluation Montage ([IndoLEM](#)) and Indonesian Bidirectional Encoder Representations from Transformers ([IndoBERT](#));
- Indonesian Natural Language Understanding ([IndoNLU](#)); as well as
- Indonesian Natural Language Generation ([IndoNLG](#)) and Indonesian Natural Language Inference ([IndoNLI](#)).

Recently available, but not included in our study as it was published after our analysis was complete, [Aji et al. \(2022\)](#) provide a detailed discussion of NLP for the 700+ languages spoken in Indonesia. They outline challenges for NLP in Indonesia, describing limited resources, language diversity, orthography variation, and societal challenges such as the poor distribution of technology and education across Indonesia.

### 3.3 Highly Active Researchers and Research Hubs

Highly active researchers in the field are identified in Figure 5. While we made substantial efforts to ensure author publications were grouped accurately, name variations appeared to be prevalent in this field. We concentrated our efforts on normalizing the raw list of the top 50 authors. In contrast to broader trends ([Mohammad, 2020](#)), we note that 7 of the 11 authors in Figure 5 are female, though some are not first authors on many papers.

Research hubs in Indonesia and Malaysia are illustrated in Figure 6. The affiliations of the 25 authors with the most publications were used to identify these hubs. All affiliated universities listed by these 25 authors (as indicated in their most recent publication which met our inclusion criteria) were in either Malaysia or Indonesia. While there was an even spread between the two countries, overall Malaysia dominated with a ratio of 14:11 affiliations in Malaysia and Indonesia, respectively.

<sup>8</sup>See, for example, [Cahya Wirawan’s pre-trained Wikipedia model](#).

### 3.4 Education Specific Studies

The number of education specific studies was 41 (see Appendix A), based on the title and abstract. Of these 41 studies, 15 focused on assessment, with an emphasis on expediting and improving the efficiency of grading and providing feedback. Earlier studies (2016–2018) tended to focus on word-level error correction and short-answer grading while later studies (2019–2021) seemed to address whole of text evaluation, assessment task design (particularly questioning techniques), and providing feedback. Within the limited time frame of our study, we tentatively noted a shift from micro language level applications and their intrinsic evaluations to more macro, holistic language use applications that proceed to extrinsic or broader NLP evaluations.

A portion of education studies considered teaching practices and teacher training. Generally the studies reflected the design of our search-terms to target Indonesian language teaching; 10 papers were geared towards using NLP to improve the teaching and learning of Indonesian/Malay for non-background language learners. Bahasa Indonesia bagi Penutur Asing (BIPA — *Indonesian language for Foreign Learners*) and the Malay equivalent were discussed separately. Two studies were related to using NLP to improve the training of teachers of Indonesian as a foreign language. Another 2 studies focused on NLP for improving the teaching of translation for local students (i.e., Indonesian background speakers). Beyond studies from a language teaching setting, a further 6 studies related to instruction in general or other areas of the curriculum such as Mathematics, study skills, and values education.

Overall the body of work indicates a need for greater resourcing generally, and greater resourcing in education, with a shift towards more sophisticated language concerns and potential uses for these methods. Pleasingly, researchers identified for a high number of publications in Figure 5, such as Amalia, A<sup>9</sup> were also identified among those developing NLP for education ([Amalia et al., 2019a](#)), indicating high profile NLP researchers are invested in education sector applications.

## 4 Discussion

This study sheds significant light on the state of play and progress of Indonesian and Malay NLP.

<sup>9</sup>(see also name variant: *Amalia*, *Amalia* and Google Scholar profile *Amalia, Mahdi*)

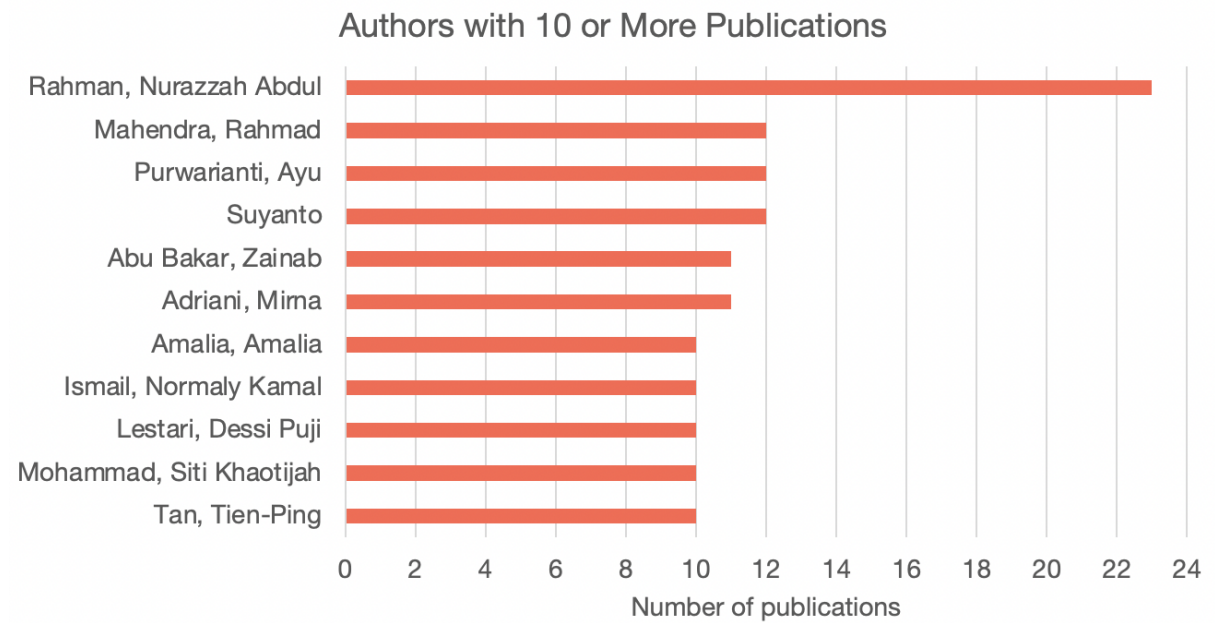


Figure 5: Authors with 10 or More Publications



Figure 6: Author Affiliation of the Top 25 Authors with Most Publications

We make the following 7 recommendations and outline our related contributions to encourage collaboration and support appropriate investment in the development of Indonesian and Malay NLP, and its application in education.

#### 4.1 Recommendations

##### 1. Broader adoption of best-practices for findable, open, sustainable, and future-proof data.

All 15 reviews raised the difficulty of locating data, tools, and existing work as a significant problem.

Our study responds to this problem and is unique in that Appendix B offers a catalogue of recent work, identifies a variety of openly shared datasets and tools, and locates research hubs. Our results complement reviews such as [Lan and Logeswaran \(2020\)](#) and [Jiang et al. \(2020\)](#) by providing an empirical picture of published research on Indonesian and Malay NLP. While our study was not specifically focused on corpora like [Awang Abu Bakar et al. \(2018\)](#), over 50 of the papers listed at the top of ‘Statistical Work’ in Appendix B point to

datasets which may be useful to future projects.

Useful advice to implement the FAIR Principles (Findable, Accessible, Interoperable, Reusable) and further advice for individual researchers/teams to develop metadata, choose file formats, and think beyond their immediate plans for linguistic data is set out by Janda (2022) and Mattern (2022), respectively. Funding requirements that encourage data reuse (given ethics restraints) and which provide financial support for adequate digital stewardship are recommended.

## **2. Expanded evaluation methods and datasets, and negative result publication**

As identified by Gunawan and Amalia (2018) and Widodo et al. (2021), evaluation of Indonesian and Malay NLP is poorly supported due to a lack of clear methods and few reference datasets. Open, accessible data from studies can assist with this, but to encourage further efficiency in the field, we also recommend authors consider the publication of ‘unsuccessful’ experiments in venues such as *Workshop on Insights from Negative Results in NLP* and organize or participate in evaluation challenges (a.k.a. shared tasks) and their workshops, for example, as part of ACL conferences.

## **3. Collaboration and connection between Indonesian and Malay NLP research and projects to speed development and allow cross-fertilisation**

Many of the reviews discussed in our results focused on Malaysian research specifically looking at Malay NLP. By using both Indonesian and Malay in our search terms we connect these reviews to the work of Indonesian authors. To illustrate, Han-dayani et al. (2018), Abu Bakar et al. (2020), and Abdullah et al. (2021) examine one study which included Malay in the application of multilingual sentiment analysis. Our findings connect this work in Malay to more recent work by Tho et al. (2021), who looked at Indonesian and Javanese code-mixed sentiment analysis.

Indonesian and Malay are closely related (Sneddon, 2003). With a caveat that corpus metadata must clearly describe which languages are present, and that projects must clearly state how Indonesian and Malay are used in training data, we recommend future work seek out synergies that could be leveraged by using both languages.

## **4. Flexible author name formats and consistent author name use**

Many authors of studies we included had only one

name, but appeared to double this name in some publications but not others, perhaps to suit forms built with an (eurocentric) expectation of family names. Similarly, many authors with lengthy names used various forms.

We recommend publishers adapt their submission forms to accommodate diverse name traditions and support existing unique author identifiers (e.g., the ORCID system). We also recommend authors choose a publication name and use it as consistently as possible to increase the findability of their work.

## **5. Investment in spoken language data and transcription protocols**

Our findings indicate only modest developments of ‘later-generation’ NLP in Indonesian and Malay. Significant investment is needed to give users of these languages access to a broader gamut of NLP applications, including applications in the education sector.

In this space it is also essential to recognise differences in the actual usage of these languages in real-life, spoken situations. Transcription which records code-mixed and often diglossic use of spoken varieties of Indonesian and Malay in a machine readable format needs to be investigated and scrutinised (Maxwell-Smith et al., 2020).

## **6. Investment in other languages of Indonesia and Malaysia**

As a necessary endeavour for equitable access to advances in NLP for speakers, and to limit the further endangerment of many languages as a consequence of the expansion of Indonesian (Zein, 2020), we recommend simultaneous investment in other languages of Indonesia and Malaysia. Linked to Recommendation 5, to reflect actual usage and to allow NLP to be useful in real-world contexts where code-mixing is the norm, investment in other languages is also likely crucial.

## **7. Education and NLP researchers should consider the use of datasets by researchers outside their field**

A research project such as ours, investigating teacher-speech and teaching materials for Indonesian language teaching (Maxwell-Smith et al., 2020) should take advantage of human language technologies. This article contributes a language-specific characterization of the field which will help scope future projects.

Education researchers should be aware that computational methods such as data normalization scripts and stemming tools are yet to be fully de-

veloped for their use with the Indonesian language. If working with spoken language, ASR toolkits for working on low resource languages are suitable for consideration but may require significant investment of time and training before they are capable of managing complex code-switching behaviours common in education settings.

For education researchers and teachers to use NLP resources they need clear information about the profile of language/s in corpora and also about what data has been used when training models/tools. This allows proper assessment of the cultural and political suitability of NLP resources.

Education researchers also need to consider the possible use of datasets by researchers outside their field. Ensuring data they collect is recorded in ‘future-proof’ formats and prepared with consideration of the FAIR principles (see Recommendation 1 — Janda (2022) and Mattern (2022)) is an investment which encourages NLP applications specifically built for or amenable to education settings.

## 4.2 Limitations and Future Work

With regard to the limitations of this study, we employed a ‘light-touch’, subjective coding method with a discrete set of class labels to scope relevant literature; we did not undertake the act of synthesis (Peters et al., 2015). We screened only the title and abstract for the vast majority of references. Unintentional misinterpretation could have taken place. Our analysis provides an approximate area within NLP for each reference to assist researchers studying an NLP application or use-case. Researchers interested in a particular algorithm (e.g., Random Forest Decision Trees or Transformers), or the use of a particular performance indicator (e.g., F1 or Word Error Rate), might not find our work as useful, but we encourage them to scan related categories in Appendix A for work relevant to their interest. Most references were labelled as belonging to multiple categories, with the identification of the first category an educated but ultimately subjective decision. Reading every study carefully beyond title and abstract was beyond the scope of this study.

Future studies to target Indonesian and Malay language publications may identify further literature on Indonesian and Malay NLP. Unfortunately, our initial searches through databases such as the University of Indonesia’s [Research Portal](#), produced varied results, with a large proportion of returned studies not necessarily having been as rig-

orously peer-reviewed (encompassing for example many ‘skripsi’ or honours dissertations). Indonesia’s national library service [OneSearch](#) has grown dramatically, and with over 3748 libraries affiliated in February 2022, it should also be included in future reviews of Indonesian and Malay NLP.

Since we conducted our review, Aji et al. (2022) have proposed potential research directions in the Indonesian context such as data-efficient and compute-efficient NLP. Given the low number of studies in our *Speaker Dialogue Systems* class, we support their call for “NLP Beyond Text”. The ‘super-glossic’ translanguaging practices of Indonesia (Zein, 2020), and language classrooms (Maxwell-Smith et al., 2020), correspond with their call for “Robustness to Code-mixing and Non-Standard Orthography”. Applications of Indonesian NLP necessitate involvement with other languages of Indonesia and inevitably impact many at-risk languages. There is an ethical obligation for “careful assessment of individual usage scenarios of language technology, so they are implemented for the good of the local population” (Aji et al., 2022).

## 5 Conclusion

Overall, this scoping study provides a baseline picture of Indonesian and Malay NLP. It shows an emerging research community engaged with the wide range of NLP advances identified in 2015 by Hirschberg and Manning. Researchers in the field continue to experience difficulties in benchmarking performance without reliable evaluation techniques and reference datasets, re-engineering of loaned preprocessing tools from English NLP, and thankless tasks such as the creation of custom datasets and resources. NLP applications in education are limited, as are tools for language which is not in text format. Our results highlight the importance of creating and releasing well-described and maintained resources openly and fostering collaboration. [IndoLEM-IndoBERT](#), [IndoNLU](#), [IndoNLG](#), and [IndoNLI](#) are notable releases that are already helping to orientate researchers and future projects using Indonesian and Malay NLP.

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## A Appendix

A more accessible table will be available [here](#).

Table 1

| Education Specific Studies                             |                        |       |
|--------------------------------------------------------|------------------------|-------|
| Title                                                  | Author                 | Year  |
| The Development of an Audible Pattani Malay- ...       | Boonkwan et al.        | 2016  |
| A corpus platform of Indonesian academic language      | Kwary                  | 2019  |
| U-tapis: Automatic spelling filter as an effort to ... | Mediyawati et al.      | 2021  |
| Word level auto-correction for latent semantic ...     | Ratna et al.           | 2017  |
| The development of Indonesian POS tagging sys ...      | Muljono et al.         | 2017c |
| A morphophonemic analysis on the affixation in ...     | Ampa et al.            | 2019  |
| Learning Indonesian Frequently Used Vocabulary ...     | Lin et al.             | 2019b |
| Towards developing colloquial Indonesian lan ...       | Nataprawira and Carey  | 2020  |
| Pengajaran bahasa dan pemerolehan bahasa ke ...        | Rosiyana               | 2020  |
| Cross-corpus native language identification via ...    | Rangel et al.          | 2018  |
| Acquiring Extended Units of Meaning: The Role ...      | Suhardijanto and Putra | 2019  |
| Designing Phonetic Alphabet for Bahasa Indone ...      | Karlina et al.         | 2020  |
| Indonesian essay grading module using Natural ...      | Ajitiono and Widyani   | 2017  |
| Automated Bahasa Indonesia essay evaluation ...        | Amalia et al.          | 2019a |
| Exploiting Syntactic Similarities for Preposition ...  | Irmawati et al.        | 2016  |
| Vocabulary Load on Two Mainstream Indonesian ...       | Destiani et al.        | 2018a |
| Perbandingan Deiksis pada Dua Buku Ajar: Anal ...      | Destiani et al.        | 2018b |
| Pengembangan kamus pemelajar Bahasa Indone ...         | Fadly                  | 2018  |
| Teaching Specific Purpose Translation: Utiliza ...     | Siregar                | 2017  |
| Theme markedness in the translation of student ...     | Sofyan and Tarigan     | 2018  |
| Strategi Pengukuran Upaya Berbahasa Menerusi ...       | Redzwan et al.         | 2020  |
| Generating artificial error data for Indonesian ...    | Irmawati et al.        | 2017b |
| Menangani Kekaburan Kemahiran Prosedur dan ...         | Anida et al.           | 2019  |
| Environmental awareness content for character ...      | Rahmawati et al.       | 2020  |
| Inquisitive semantic analysis of Malay language ...    | Subet and Md Nasir     | 2019  |
| An experimental study of text preprocessing tech ...   | Hasanah et al.         | 2018  |
| N-Gram Keyword Retrieval on Association Rule ...       | Setiawan et al.        | 2018  |
| Semi-supervised learning self-training for Indone ...  | Wulan and Supangkat    | 2018  |
| Evaluating rnn architectures for handling imbal ...    | Christianto et al.     | 2020  |
| A comparison of supervised text classification ...     | Dhammajoti et al.      | 2020  |
| Automatic Indonesia's questions classification ...     | Kusuma et al.          | 2016  |
| Answer categorization method using K-means for ...     | Ratna et al.           | 2019  |
| Knowing Right from Wrong: Should We Use ...            | Septiandri et al.      | 2020  |
| WPS: Application for Generating Answer of ...          | Oktavia et al.         | 2021  |
| Question generation model based on key-phrase, ...     | Wijanarko et al.       | 2021  |
| Developing Question Generation System for Ba ...       | Wisnu Prabowo et al.   | 2021  |
| Applications of natural language processing in ...     | Maxwell-Smith et al.   | 2020  |
| Developing an online self-learning system of In ...    | Muljono et al.         | 2016  |
| Automatic Pronunciation Generator for Indone ...       | Hoesen et al.          | 2019  |
| Anita: Intelligent Humanoid Robot with Self- ...       | Andreas et al.         | 2019  |
| A novel model and implementation of humanoid ...       | Budiharto et al.       | 2021  |
| End of Table                                           |                        |       |

## B Appendix

A more accessible table will be available [here](#).

Table 2

| Broad NLP                                              |                             |       |
|--------------------------------------------------------|-----------------------------|-------|
| Title                                                  | Author                      | Year  |
| IndoLEM and IndoBERT: A Benchmark Dataset ...          | Koto et al.                 | 2020b |
| Unstructured Malay Text Analytics Model in Crime       | Mohemad et al.              | 2020c |
| A new framework for information system devel ...       | Sukarsa et al.              | 2018  |
| An overview of BPPT's Indonesian language re ...       | Gunarso et al.              | 2016  |
| Challenges and development in Malay natural lan ...    | Lan and Logeswaran          | 2020  |
| Statistical and Corpus Work                            |                             |       |
| Title                                                  | Author                      | Year  |
| The Development of an Audible Pattani Malay- ...       | Boonkwan et al.             | 2016  |
| Linking the TUFs Basic Vocabulary to the Open ...      | Bond et al.                 | 2020  |
| Hypernym-Hyponym Relation Extraction from ...          | Nityasya et al.             | 2019  |
| Linguistik Korpus Kuantitatif dan Kajian Seman ...     | Rajeg                       | 2020  |
| Characteristics of Malay translated hadith corpus      | Sazali et al.               | 2020  |
| Syllabification Model of Indonesian Language ...       | Fanani and Suyanto          | 2021  |
| A corpus platform of Indonesian academic language      | Kwary                       | 2019  |
| Examining the writing genre in journal articles of ... | Wiratno and Dzakiria        | 2016  |
| An annotated news corpus of Malaysian Malay            | Chung and Shih              | 2019  |
| Introduction of the Asian Language Treebank            | Riza et al.                 | 2017  |
| Information extraction: Evaluating named entity ...    | Sazali et al.               | 2017  |
| Comparative study on corpus development for ...        | Din et al.                  | 2017  |
| Building the Pornography Corpus for Bahasa In ...      | Gunawan et al.              | 2019c |
| Building a Malay-English code-switching subjec ...     | Kasmuri and Basiron         | 2019  |
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| An Ontological Approach towards Dialogue ...           | Mohd Yunus et al.           | 2017  |
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| Evaluation of Energy and Duration on Malay ...         | Hanum and Bakar             | 2016a |
| Prosodic breaks on Malay speech corpus: Evalua ...     | Hanum et al.                | 2017  |
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| Stress predictors in a Papuan Malay random forest      | Kaland et al.               | 2019  |
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| Development of under-resourced Bahasa Indone ...       | Cahyaningtyas and Arifianto | 2018  |
| Generative Indonesian Conversation Model using ...     | Chowanda and Chowanda       | 2018  |
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Continuation of Table 2

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| An integrated semi-automated framework for ...         | Kaity and Balakrishnan        | 2020  |
| BMBI: A Development of a Special Corpus on ...         | Rumaisa et al.                | 2020  |
| Sentiment analysis in Indonesian and French by ...     | Shalunts et al.               | 2018  |
| Preliminary Research Design on Sensor Data ...         | Aulia et al.                  | 2020  |
| Review on the Role of Social Media for Dengue ...      | Kannan et al.                 | 2019  |
| Twitter corpus creation: The case of a Malay ...       | Saloot et al.                 | 2016  |
| An Application that Invites Users to Participate ...   | Thamrin et al.                | 2019b |
| A publicly available Indonesian corpora for auto ...   | Koto                          | 2016  |
| Development of multilingual social media data ...      | Rumaisa et al.                | 2019  |
| Bahasa Indonesia text corpus generation using ...      | Amalia et al.                 | 2019b |
| WatsaQ: Repository of Al Hadith in Bahasa (Case ...    | Aulia et al.                  | 2017a |
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| Building Corpus in Bahasa Indonesia for Porno ...      | Chandra et al.                | 2019  |
| Building a web-based application for language ...      | Dinakaramani and Suhardijanto | 2019  |
| Development of a Web-based Jahai-Malay Lan ...         | Mohtar et al.                 | 2021  |
| A Review on Building Bilingual Comparable Cor ...      | Nasharuddin et al.            | 2018  |
| Linguistic studies using large annotated corpora: ...  | Nomoto and Moeljadi           | 2019  |
| Introducing the Asian language treebank (ALT)          | Thu et al.                    | 2016  |
| Bahasa Melayu sebagai Bahasa Ilmu (BMBI) di ...        | Yusof et al.                  | 2017  |
| A dependency annotation scheme to extract syn ...      | Irmawati et al.               | 2017a |
| Domain-specific stop words in Malaysian parlia ...     | Rahman et al.                 | 2021a |
| Transforming semi-structured indigenous dictio ...     | Ranaivo-Malançon et al.       | 2017  |
| Rule-based text normalization for Malay social ...     | Ariffin and Tiun              | 2020  |
| Evaluating the use of word embeddings for part- ...    | Abka                          | 2017  |
| Information Retrieval System to Find Articles and ...  | Sulaeman et al.               | 2020  |
| U-tapis: Automatic spelling filter as an effort to ... | Mediyawati et al.             | 2021  |
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| Incorporating Knowledge Base in Unsupervised ...       | Rifin and Hamzah              | 2017  |
| Movie Summarization based on Indonesian Subti ...      | Situmeang et al.              | 2019  |
| Semantic similarity measures for Malay-English ...     | Mahadzir et al.               | 2018  |
| Recognizing and normalizing temporal expres ...        | Mirza                         | 2016  |
| Automatic Grammar Checking System for Indone ...       | Rahutomo et al.               | 2018  |
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| Proposal: A Hybrid Dictionary Modelling Ap ...         | Nor Azlizawati Binti et al.   | 2017  |
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| Review and Visualization of Facebook's FastText ...    | Young and Rusli               | 2019  |
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Continuation of Table 2

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| Word level auto-correction for latent semantic...   | Ratna et al.            | 2017  |
| Evaluating Word Embeddings for Indone...            | Rizal and Stymne        | 2020  |
| Designing and implementing parsing for ambigu...    | Soyusiawaty and Aribowo | 2016  |
| Word Embedding for Small and Domain-specific...     | Tiun et al.             | 2020a |
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| Towards stemming error reduction for Malay texts    | Kassim et al.           | 2019  |
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| Design Consideration of Malay Text Stemmer...       | Kassim et al.           | 2020a |
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| Enhanced rules application order to stem affixa...  | Kassim et al.           | 2016a |
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| Non-formal affixed word stemming in Indonesian...   | Putra et al.            | 2018a |
| Accuracy measurement on Indonesian non-formal...    | Putra et al.            | 2019  |
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| A comparison of different part-of-speech tagging... | Amrullah et al.         | 2017  |
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| Evaluating the Morphological and Capitalization...  | Manik et al.            | 2019  |
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| An evaluation of MorphInd's morphological an...     | Prihantoro              | 2021  |
| Rule-based Part of Speech Tagger for Indonesian...  | Purnamasari and Suwardi | 2018  |
| Evaluating lstm networks, hmm and wfst in...        | Tan et al.              | 2017b |
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| Implementation of ontology-based on Word2Vec...     | Togatorop et al.        | 2020  |
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| Breakdown film script using parsing algorithm       | Wahana et al.           | 2020  |
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| Indonesian Parsing using Probabilistic Context-...  | Cahyani et al.          | 2020  |
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Continuation of Table 2

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| Tackling the Low-resource Challenge for Canoni ...     | Mager et al.                     | 2020  |
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| Ensemble technique utilization for Indonesian de ...   | Rahman and Purwarianti           | 2017  |
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| Exploring Lexical Differences Between Indone ...       | Lin et al.                       | 2019c |
| A Corpus Driven Analysis of Representations ...        | Nor Fariza Mohd et al.           | 2019  |
| Exploiting Malay corpus on islamic issue using ...     | Setik et al.                     | 2018  |
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| Comparison of the themes of Malaysian Friday ...       | Aasim Asyafi'Ie bin Ahmad et al. | 2017  |
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| Utterance-final particles in Klang Valley Malay        | Hoogervorst                      | 2018  |
| Covid-19 dalam Korpus Peristilahan Bahasa ...          | Kasdan et al.                    | 2020  |
| Gandaan Separa dalam Terminologi Bahasa ...            | Kasdan et al.                    | 2017  |
| Compilation of Malay criminological terms from ...     | Lee et al.                       | 2019  |
| Exploring Letter's Differences between Partial ...     | Lin et al.                       | 2019a |
| Hedging in the discussion sections of English and ...  | Loi and Lim                      | 2019  |
| Formation of health science terminology by users ...   | Mohamad et al.                   | 2020c |
| Politeness in communication through local chil ...     | Mohamad Nor et al.               | 2019  |
| Translation and Markedness                             | Ni et al.                        | 2018  |
| Frequency of Verbs in Lifestyle Column in the ...      | Oktavianti and Pramesti          | 2019  |
| The influence of students' L1 and spoken English ...   | Prihantoro                       | 2016  |
| Sketching the Semantic Change of Jahanam and ...       | Puspita and Yusuf                | 2020  |
| Vector Space Models and the usage patterns of ...      | Rajeg et al.                     | 2019  |

Continuation of Table 2

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| Collocation analysis of variants of intensifies in ... | Sarudin et al.                  | 2020a |
| Discourse functions of the two non-active voices ...   | Shiohara et al.                 | 2019  |
| The Framework of Multiword Expression in In ...        | Suhardijanto et al.             | 2020  |
| Acquiring Extended Units of Meaning: The Role ...      | Suhardijanto and Putra          | 2019  |
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| Frasa Topik Dan Fokus Dalam Bahasa Melayu: ...         | Sultan and Othman               | 2021  |
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| Diachronic Corpora as a Tool for Tracing Etymo ...     | Yusuf and Puspita               | 2020  |
| Representatif Leksikal Ukuran sebagai Metafora ...     | Zaini et al.                    | 2020b |
| Designing Phonetic Alphabet for Bahasa Indone ...      | Karlina et al.                  | 2020  |
| Indonesian essay grading module using Natural ...      | Ajitiono and Widyani            | 2017  |
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| Vocabulary Load on Two Mainstream Indonesian ...       | Destiani et al.                 | 2018a |
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| Pengembangan kamus pemelajar Bahasa Indone ...         | Fadly                           | 2018  |
| Fossicking in dominant language teaching: Ja ...       | Maxwell-Smith                   | 2021  |
| Teaching Specific Purpose Translation: Utiliza ...     | Siregar                         | 2017  |
| Theme markedness in the translation of student ...     | Sofyan and Tarigan              | 2018  |
| Strategi Pengukuran Upaya Berbahasa Menerusi ...       | Redzwan et al.                  | 2020  |
| Generating artificial error data for Indonesian ...    | Irmawati et al.                 | 2017b |
| Menangani Kekaburan Kemahiran Prosedur dan ...         | Anida et al.                    | 2019  |
| Environmental awareness content for character ...      | Rahmawati et al.                | 2020  |
| Development of Malay word materials for ...            | Yusof et al.                    | 2019  |
| Exploring gender issues associated with ...            | Aziz                            | 2019  |
| “Happiness” in Bahasa Indonesia and its implica ...    | Effendi and Muchammadun         | 2018  |
| Defying the global: The cultural connotations of ...   | Hashim and Rahim                | 2016  |
| The implicit meaning in Malay figurative lan ...       | Mansor and Jalaluddin           | 2016  |
| “Is Selangor in Deep Water?”: A Corpus-driven ...      | Norsimah Mat et al.             | 2019  |
| Linguistic Representation of Violence in Judicial ...  | Othman et al.                   | 2019  |
| Text mining of online job advertisements to iden ...   | Panggih Kusuma et al.           | 2020  |
| Inquisitive semantic analysis of Malay language ...    | Subet and Md Nasir              | 2019  |
| Spotlight on LGBT in Malaysian online newspa ...       | Ting et al.                     | 2021  |
| The polarity of war metaphors in sports news: A ...    | Hua et al.                      | 2021  |
| Communicating insults in cyberbullying                 | Hua et al.                      | 2019  |
| Analisis korpus terhadap idiom Bahasa Indonesia ...    | Paramarta                       | 2018  |
| Conceptual metaphor and linguistic manifesta ...       | Saad et al.                     | 2018b |
| The relationship between astronomy and architec ...    | Sarudin et al.                  | 2020b |
| Beyond the closet? The trends and visibility of ...    | Subir                           | 2019  |
| Trend Penggunaan Bahasa Samar dalam Persidan ...       | Tan et al.                      | 2017a |
| Form and function of negation in German and ...        | Triyono et al.                  | 2020  |
| Bòsò Walikan Malang’s Address Practices                | Yannuar et al.                  | 2017  |

Continuation of Table 2

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| House building tips (HBT) corpus dataset as a ...       | Zaini et al.               | 2021  |
| Understanding quotation extraction and attribu ...      | Purnomo W.P et al.         | 2020  |
| An automatic health surveillance chart interpreta ...   | Aulia and Barmawi          | 2016  |
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| Relationship analysis of keyword and chapter in ...     | Chua and Nohuddin          | 2017  |
| Relation extraction using dependency tree kernel ...    | Esperanti and Purwarianti  | 2016  |
| An experimental study of text preprocessing tech ...    | Hasanah et al.             | 2018  |
| Relation Detection for Indonesian Language Us ...       | Hasudungan and Purwarianti | 2019  |
| Classification of short possessive clitic pronoun ...   | Noor et al.                | 2020  |
| Assessing Suitable Word Embedding Model for ...         | Phua et al.                | 2020  |
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| Transliteration engine for union catalogue of ...       | Razak et al.               | 2018  |
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| Exploring Multilingual Syntactic Sentence Repre ...     | Liu et al.                 | 2019a |
| Transfer Building of Multiword Expression Re ...        | Liu and Wang               | 2020  |
| Reclassification of the Leipzig Corpora Collec ...      | Nomoto et al.              | 2018a |
| Learning Indonesian-Chinese Lexicon with Bilin ...      | Qiu and Zhu                | 2016  |
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| Towards a Standardized Dataset on Indonesian ...        | Khairunnisa et al.         | 2020  |
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| Rule-based Approach on Extraction of Malay ...          | Zamri Abu et al.           | 2017  |
| A review of named entity recognition and classifi ...   | Mohemad et al.             | 2020a |
| Detecting proper nouns in Indonesian-language ...       | Raharjo et al.             | 2020  |
| Named entity recognition on Indonesian tweets ...       | Azarine et al.             | 2019  |
| Named entity recognition on Indonesian Twitter ...      | Rachman et al.             | 2018b |
| An enhanced Malay named entity recognition us ...       | Asmai et al.               | 2018  |
| Named entity recognition using fuzzy c-means ...        | Salleh et al.              | 2018  |
| Named entity recognition on Indonesian mi ...           | Taufik et al.              | 2017  |
| DBpedia entities expansion in automatically build ...   | Alfina et al.              | 2017  |
| Entity annotation WordPress plugin using ...            | Aprilius et al.            | 2017  |
| Developing name entity recognition for structured ...   | Azzahra et al.             | 2020  |
| Detection of compound word with combination ...         | Bakar et al.               | 2017  |
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| Automatic detection of compound word in Malay ...       | Bakar et al.               | 2018b |
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| Medical Named Entity Recognition for Indone ...         | Rahman                     | 2018  |
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| A Malay named entity recognition using condi ...        | Salleh et al.              | 2017  |
| Low Complexity Named-Entity Recognition for ...         | Sukardi et al.             | 2020  |
| Building Low-Resource NER Models Using Non- ...         | Tsygankova et al.          | 2021  |

Continuation of Table 2

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| Developing Indonesian corpus of pornography ...        | Andriansyah et al.            | 2018  |
| Bahasa Indonesia pre-trained word vector genera ...    | Putri et al.                  | 2021  |
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| N-Gram Keyword Retrieval on Association Rule ...       | Setiawan et al.               | 2018  |
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| Graph-based text representation for Malay trans ...    | Alias et al.                  | 2017a |
| Building automatic mind map generator for natu ...     | Yulianto and Mariyah          | 2017  |
| Neural sequence-to-sequence learning of internal ...   | Ruzsics and Samardzic         | 2017  |
| Classification of user comment using word2vec ...      | Kurnia and Girsang            | 2021  |
| Short Message Service (SMS) Spam Filtering us ...      | Theodorus et al.              | 2021  |
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| Long short-term memory for hate speech and abu ...     | Salim and Suhartono           | 2021  |
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| Multi-Label Topic Classification of Hadith of ...      | Abu Bakar et al.              | 2019a |
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| An evolutionary-based term reduction approach ...      | Alfred et al.                 | 2017  |
| Assessing factors that influence the performances ...  | Alfred et al.                 | 2016  |
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Continuation of Table 2

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Continuation of Table 2

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Continuation of Table 2

| Title                                                      | Author                      | Year  |
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| A Neural Machine Translation Approach for ...              | Low et al.                  | 2020  |
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| <i>See also</i> - A review on Indonesian machine trans ... | Rahutomo et al.             | 2019  |
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| Improved Transcription and Speaker Identifica ...          | Andra and Usagawa           | 2021  |

Continuation of Table 2

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| Speech-to-Text Conversion in Indonesian Lan ...       | Dwijayanti et al.        | 2021  |
| Comparison of feature extraction MFCC and LPC ...     | Endah et al.             | 2017  |
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| Voiced and unvoiced separation in Malay speech ...    | Hanifa et al.            | 2019  |
| Wavelet based feature extraction for the vowel sound  | Hidayat et al.           | 2016  |
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| Sentence-level Indonesian lip reading with spa ...    | Maulana and Fanany       | 2018b |
| Sphinx4 for Indonesian continuous speech recog ...    | Muljono et al.           | 2017b |
| Indonesian graphemic syllabification using a near ... | Parande and Suyanto      | 2019  |
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Continuation of Table 2

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| Virtual phone discovery for speech synthesis with ...   | Nayak et al.                 | 2019  |
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| Aspect-based Opinion Mining on Beauty Product ...       | Mahfiz and Romadhony         | 2020  |
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| Sentiment analysis system for movie review in ...       | Nurdiansyah et al.           | 2018  |
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| Pair Extraction of Aspect and Implicit Opinion ...      | Setiowati et al.             | 2019  |
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| Sentiment analysis of economic news in Bahasa ...       | Zamahsyari and Nurwidiantoro | 2017  |

Continuation of Table 2

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| Multi-Classes Emotion Detection for Unbalanced ...      | Farsiah et al.              | 2020  |
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| Classification of Twitter data by sentiment analy ...   | Mohamad et al.              | 2020a |
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| Applying Opinion Mining Technique on Tourism ...        | Situmorang et al.           | 2019  |
| Does it make you sad? A lexicon-based sentiment ...     | Suryadi                     | 2021  |
| Emotion analysis using self-training on ...             | Tan et al.                  | 2020  |
| Sentiment analysis for telco popularity on Twitter ...  | Tan et al.                  | 2016  |
| Hate speech classification in Indonesian language ...   | Taradhita and Putra         | 2021  |

Continuation of Table 2

| Title                                                   | Author                 | Year  |
|---------------------------------------------------------|------------------------|-------|
| Sentiment Analysis of Indonesians Response to ...       | Tauhid and Ruldeviyani | 2020  |
| Code-mixed sentiment analysis of Indonesian lan ...     | Tho et al.             | 2021  |
| Simulation of marketplace customer satisfaction ...     | Turdjai and Mutijarsa  | 2017  |
| Hashtag Global Surgery: The Role of Social Me ...       | Vervoort and Luc       | 2020  |
| School from home situation in Indonesia: An ex ...      | Wahyuni et al.         | 2020  |
| Measuring happiness in large population                 | Wenas et al.           | 2016  |
| Sentiment analysis of informal Malay tweets with ...    | Ying et al.            | 2020  |
| Developing cross-lingual sentiment analysis of ...      | Zabha et al.           | 2019  |
| Automatic Labelling of Malay Cyberbullying ...          | Maskat et al.          | 2020  |
| Personality prediction based on Twitter informa ...     | Ong et al.             | 2017  |
| Personality Modelling of Indonesian Twitter ...         | Ong et al.             | 2021  |
| Profiling analysis of DISC personality traits based ... | Utami et al.           | 2019a |
| Supervised learning and resampling techniques ...       | Utami et al.           | 2021  |
| D-Loc Apps: A Location Detection Application ...        | Fitrianah et al.       | 2020  |
| Music interest classification of Twitter users us ...   | Yusra et al.           | 2017  |
| Lexical based sentiment analysis - Verb, adverb ...     | Shamsudin et al.       | 2016  |
| Construction of the Malay language psychometric ...     | Ahmad et al.           | 2017  |
| Hate speech detection in Indonesian language on ...     | Bunga Batara et al.    | 2019  |
| Hate speech detection in Indonesian language on ...     | Erizal et al.          | 2019  |
| Hate speech detection on Indonesian Instagram ...       | Pratiwi et al.         | 2019  |
| Hate speech detection in Indonesian language In ...     | Putra and Nurjanah     | 2020  |
| Hate speech detection in Indonesian language on ...     | Briliani et al.        | 2019  |
| Recognizing the sarcastic statement on WhatsApp ...     | Afiyati et al.         | 2018  |
| Construction of Malay abbreviation corpus based ...     | Omar et al.            | 2017  |
| Context-sensitive normalization of social media ...     | Kusumawardani et al.   | 2018  |
| A taxonomy of Malay social media text                   | Maskat and Munarko     | 2019  |
| Detecting opinion spams through supervised ...          | Hazim et al.           | 2018  |
| The development of Bahasa Indonesia corpora for ...     | Jambak and Setiawan    | 2018  |
| Review on sentiment analysis approaches for so ...      | Abdullah et al.        | 2017  |
| Sentiment Analysis of Noisy Malay Text: State ...       | Abu Bakar et al.       | 2020  |
| Emotion detection of tweets in Indonesian lan ...       | Cahyaningtyas et al.   | 2017  |
| Bias aware lexicon-based Sentiment Analysis of ...      | Hijazi et al.          | 2017  |
| Translated vs non-translated method for multilin ...    | Ibrohim and Budi       | 2019b |
| Classification and quantification of user's emo ...     | Jamaluddin et al.      | 2017  |
| A hybrid model for social media sentiment analy ...     | Putra et al.           | 2018b |
| Natural language processing based features for ...      | Suhaimin et al.        | 2017  |
| Modified framework for sarcasm detection and ...        | Suhaimin et al.        | 2019  |
| Concerns of thalassemia patients, carriers, and ...     | Phang et al.           | 2021  |

End of Table